3.1 Silicon Maintenance and Operations
4.1 R&D

Abe Seiden
UC Santa Cruz

DOE/NSF Review of U.S. ATLAS Research Program
April 9-11, 2002 - Fermilab

Overview

- **Silicon system comprised of:**
  - -Pixel detector
  - -Silicon strip system (SCT)
  - -Read Out Drivers for these two systems
- **U.S. deliverables are about 20% of total. Plan same fraction of effort during research phase.**

Institutions

SUNY Albany
Iowa State University
UC Berkeley/LBNL
University of New Mexico
Ohio State University
University of Oklahoma/Langston Univ.
UC Santa Cruz
University of Wisconsin

Management: US ATLAS

1.1.1 Pixels (Gilchriese)
1.1.1.1 Mechanics/Services (Gilchriese, Anderssen)
1.1.1.2 Sensors (Seidel, Hoeferkamp)
1.1.1.3 Electronics (Einsweiler, Denes)*
1.1.1.4 Hybrids (Skubic, Boyd, Gan)
1.1.1.5 Modules (Garcia-Sciveres, Goozen)*

1.1.2 Silicon Strips (Seiden)
1.1.2.1 IC Electronics (Grillo, Spencer)*
1.1.2.2 Hybrids (Ciocio, Senior Techs)
1.1.2.3 Modules (Haber, Senior Techs)

1.1.3 RODs (Jared, Joseph)*

*Lead for all of ATLAS
(Physicist, Engineer or Senior Tech)

Overview

Responsibilities for commissioning, maintenance and operations flow from:

- Construction Schedule.
- Responsibilities of U.S. Groups
- Development of Shared Facilities for long-term Maintenance.
- Radiation Effects on Tracker Components.

Construction Schedule

Construction Project Time Schedule:

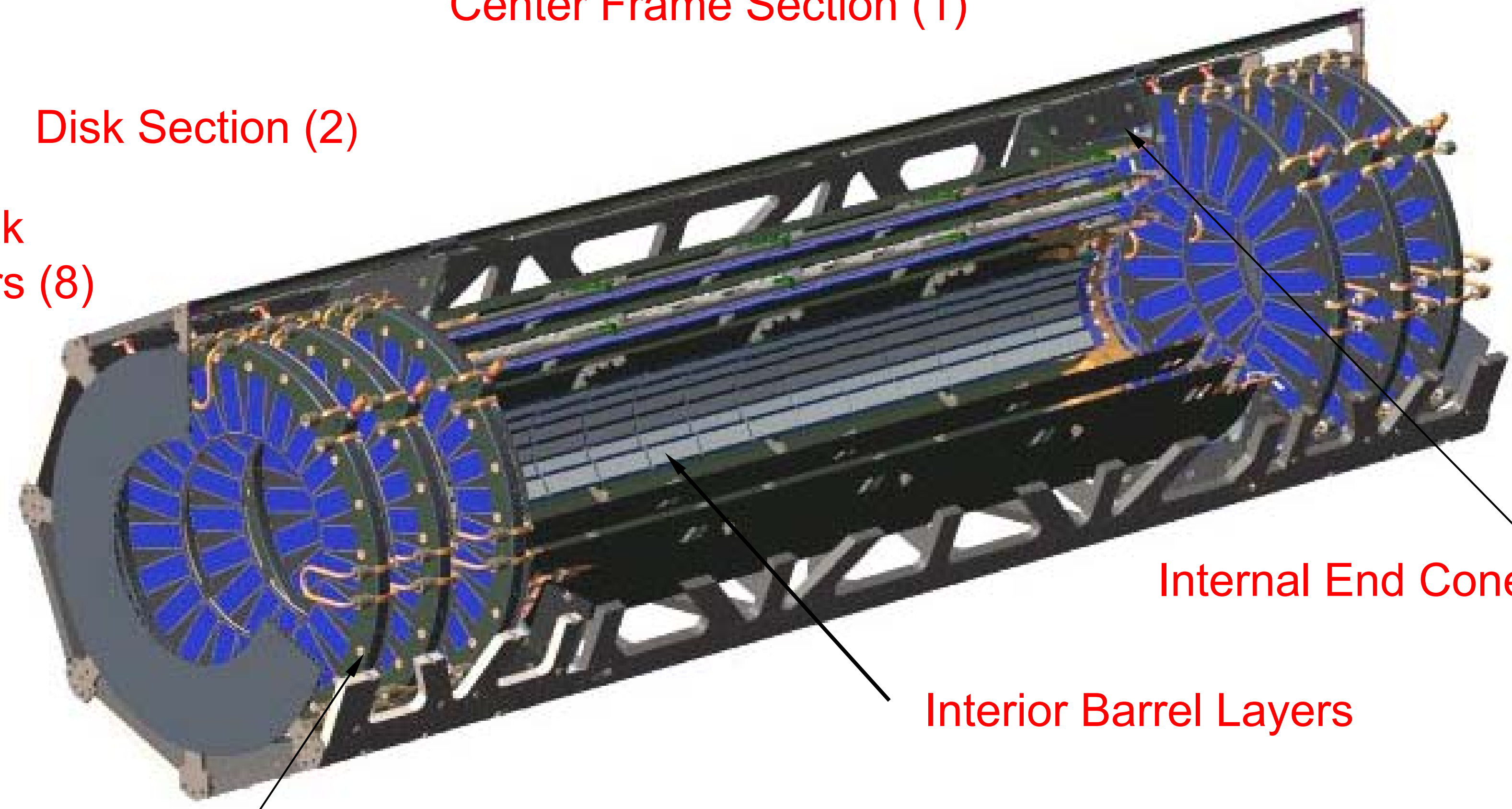
Pixels: Baseline 2-hit system ready for installation:
6/23/05

Strips: Completion of shipping of modules to England:
10/17/03

RODs: SCT RODs complete:
12/19/02

Pixel RODs complete:
3/13/03

Pixel System



(Services not shown)

Responsibilities: Pixel System

- Pixel System

  -Most of mechanics(support tube, support frame, disk region).

  -Large fraction of services(cables, piping, etc) within tracker volume.

  -About 20% of sensors(silicon detectors).

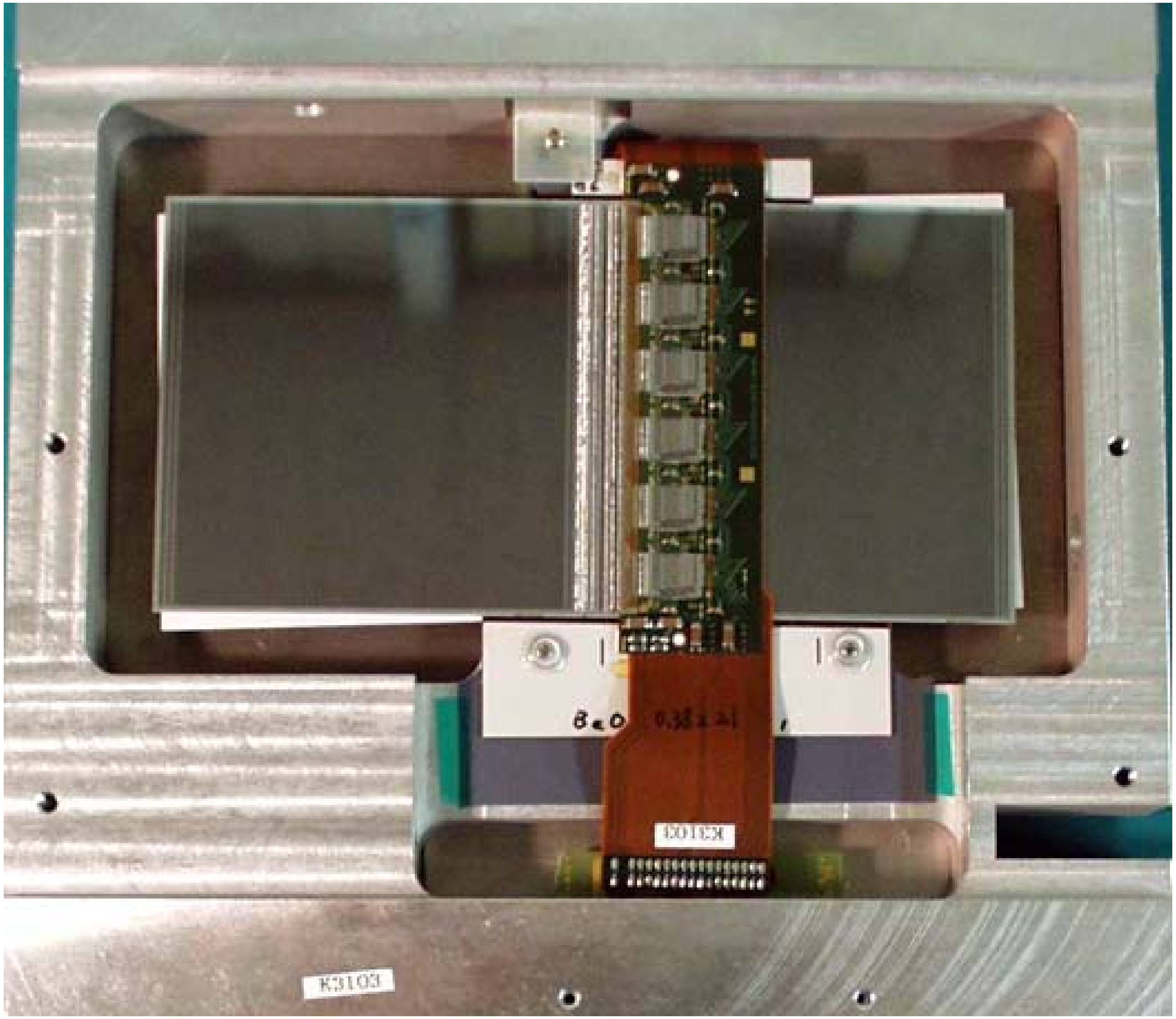
  -System management for electronics and modules.

  -Major design role in IC electronics and system engineering, about 20% of procurement.

  -Most of hybrids.

  -Module assembly/testing about 25%.

Silicon Strip System



Responsibilities: Silicon Strip(SCT) System

- Silicon Strip System

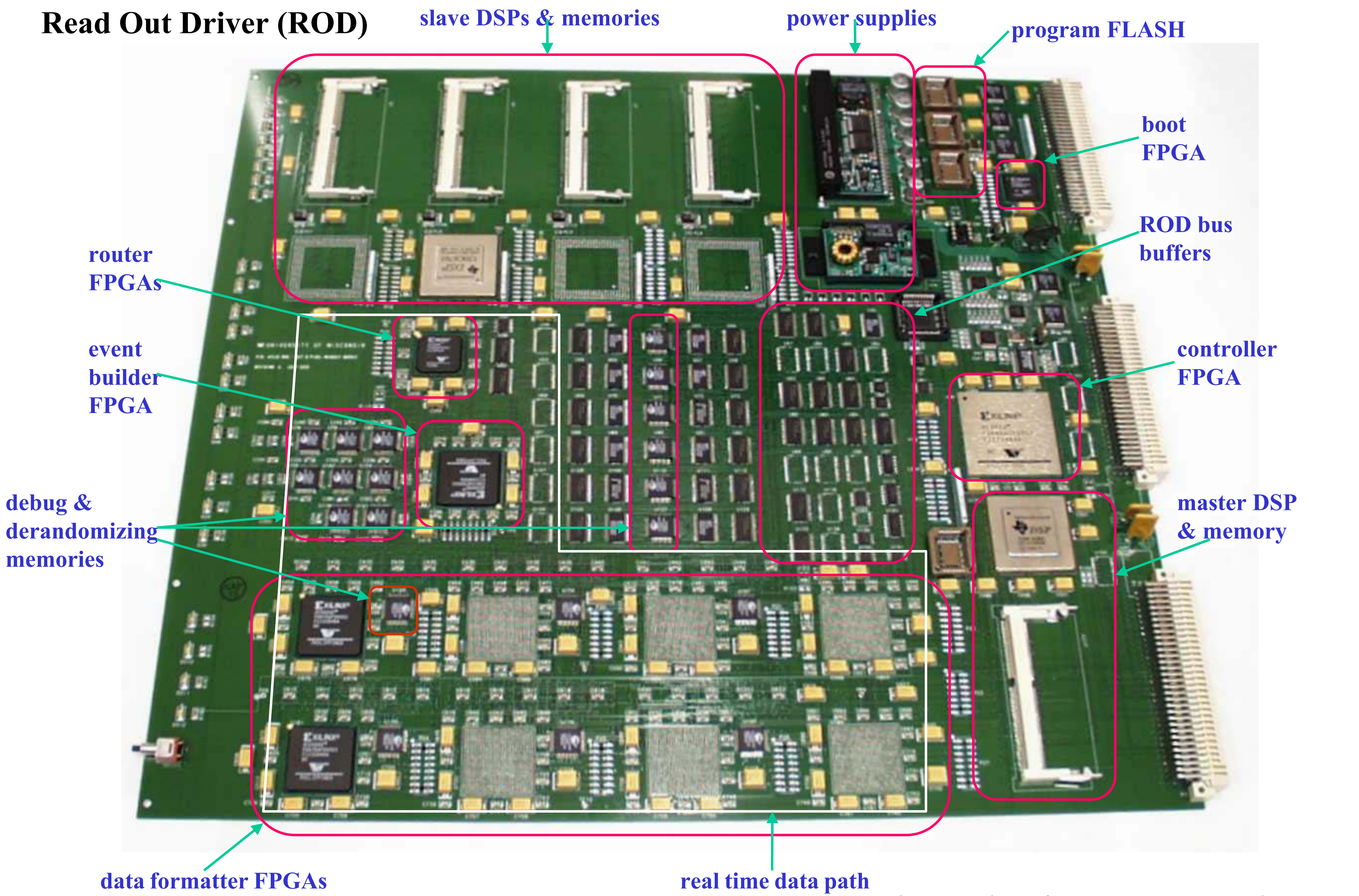
  -Major procurement of IC electronics, testing of these.

  -System management of entire electronics (front-ends to power supplies).

  -Systems engineering for electronics (grounding, shielding, cabling).

  -Construction of about one-third of barrel modules.

ROD (Read Out Driver)



Responsibilities: Read Out Drivers

- Read Out Drivers

  - -VME modules that read out both pixel and SCT modules.

  - -Unique U.S. responsibility, all modules responsibility of U.S.

  - -SCT RODs are to start fabrication in late FY02 for use at macro-assembly sites(where modules are put on mechanical structures).

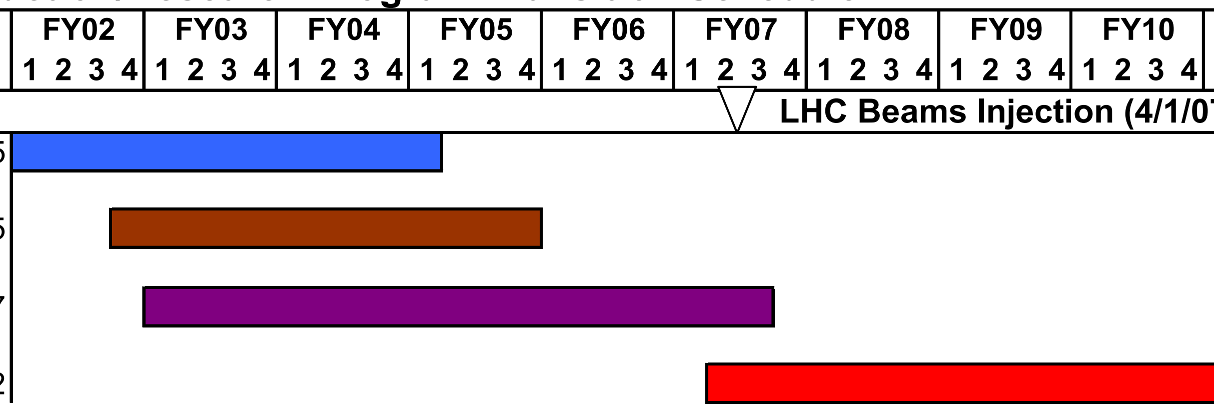
  - -Pixel RODs needed later, but possibly will be used for same purpose.

Schedule

Level 2

Construction/Research Program Transition Schedule

Subsystem	Category	Start Date	Compl Date
Silicon	Construction	N/A	1/31/05
	Installation	7/1/02	9/30/05
	Pre-Operations	10/1/02	6/30/07
	Operations	1/2/07	9/28/12



U.S. ATLAS M&O Estimates
WBS Level 4 Profile

Funding Source: All **Funding Type:** Program 4/3/02 8:15:09 AM

Institutions: All **Labor/Material:** Both

WBS Number	Description	FY 03 (k$)	FY 04 (k$)	FY 05 (k$)	FY 06 (k$)	FY 07 (k$)	FY 08 (k$)	FY 09 (k$)	FY 10 (k$)	FY 11 (k$)	FY 12 (k$)
3	U.S. ATLAS M&O Estimate	377	329	542	1509	1582	1346	1055	1094	1201	1004
3.1	Silicon	377	329	542	1509	1582	1346	1055	1094	1201	1004
3.1.1	Pixels	0	0	0	795	732	732	498	498	498	498
3.1.1.1	Pre-operations	0	0	0	795	0	0	0	0	0	0
3.1.1.2	Operations	0	0	0	0	422	422	302	302	302	302
3.1.1.3	Maintenance	0	0	0	0	310	310	197	197	197	197
3.1.2	SCT	0	229	234	333	331	119	119	119	316	119
3.1.2.1	Pre-operations	0	0	234	333	0	0	0	0	0	0
3.1.2.2	Operations	0	0	0	0	175	109	109	109	109	109
3.1.2.3	Maintenance	0	229	0	0	157	10	10	10	207	10
3.1.3	RODs	280	0	221	231	258	150	78	78	78	78
3.1.3.1	Pre-operations	0	0	221	231	0	0	0	0	0	0
3.1.3.2	Operations	0	0	0	0	222	113	41	41	41	41
3.1.3.3	Maintenance	280	0	0	0	37	37	37	37	37	37
3.1.4	Common Silicon/ID	97	100	86	150	261	346	361	400	310	310
3.1.4.1	Pre-operations	97	100	86	150	0	0	0	0	0	0
3.1.4.2	Maintenance Operations	0	0	0	0	261	346	361	400	310	310

Near Term (FY 02, 03, 04)

Major M & O responsibilities for FY 02, 03, 04:

Spares and proportional contribution to shared facilities in SR building (surface building being outfitted for tracker maintenance).

Spares in cases where obsolescence is an important factor, or where unique facilities are important:

FY02: $300k for spare SCT front-end chips. DMILL process from ATMEL is expected to soon not be available, therefore it is critical to buy spares. Would fund 8% spare chips.

FY03: $280k for 10% spare RODs.

FY04: $229k for 10% spare SCT modules (labor costs). Would follow completion of baseline deliverables, while facilities and personnel are available.

Near Term (FY 02, 03, 04)

Pre-operations:

SR building, shared facilities, for long term servicing of the tracker. Some required items: clean room; piping, cooling and ventilation; electrical items such as fiber optics, connectors PC's, racks. Cost estimates based on work of Inner Detector Steering Group. U.S. share for silicon is 14%.

U.S. Share of Costs:

FY03	FY04
\$97k	\$100k

Estimated additional costs in FY 05 and 06 are \$236k to complete facilities.

Longer Term

For SCT and RODs expect to be mainly involved in M&O starting in FY05. For Pixels starting in FY06.

M&O responsibilities will follow construction responsibilities. Expect major activities in FY06, 07, 08 during pre-operations, first operations and data collection.

Also expect some “spikes” in activity when major repairs occur, difficult to predict when.

M&O Plan: Pixels(WBS 3.1.1)

Pixels (WBS 3.1.1)

-We have projected continued support of unique U.S. deliverables in mechanics that allow removal/re-insertion of the pixel system (ME and some tech support).
-We have provided for minimal continued support of electronics (EE and some tech support).
-We have included continued critical systems engineering and software support for DAQ, calibration monitoring, etc. (John Richardson, LBNL, who will become resident At CERN.)

Strips (WBS 3.1.2)

-Systems engineering(N. Spencer from UCSC) has been vital. Continued systems engineering will be needed during pre-operations(after modules are installed on support structure at Oxford), during surface testing at CERN and during first data collection.

Rods (WBS 3.1.3)

-The RODs are a unique US responsibility so all operations and maintenance is assumed to be provided by the US.
-The manpower levels to achieve this are shown on the next page.

M&O Personnel Summary

	FY05	FY06	FY07	FY08	FY09
Pixels (WBS 3.1.1)					
Mech. Eng.		1.0	1.0	1.0	0.4
Elect. Eng.		1.0	0.5	0.5	0.2
Technician		1.5	1.8	1.8	1.4
Software		1.0	1.0	1.0	1.0
Designer		0.3			
SCT (WBS 3.1.2)					
Elect. Eng.	0.6	1.1	0.5	0.1	0.1
Technician	1.3	1.3	2.3	1.0	1.0
RODs (WBS 3.1.3)					
Elect. Eng.	1.0	1.0	1.0	0.5	0.1
Technician			0.3	0.3	0.3
Software	0.3	0.3	0.3	0.1	0.1

Base & Infrastructure FTEs by FY

Subsystem	FY05	FY06	FY07	FY08	FY09
Pixels (WBS 3.1.1)					
Faculty	1.0	2.0	2.0	1.0	0.5
Sr Research Scientist	1.0	2.0	2.0	1.0	1.0
Term Scientist	1.0	2.0	2.0	1.0	0.5
Post Doc	3.0	7.0	7.0	5.0	2.0
Grad Student	2.0	4.0	4.0	3.0	1.5
Technician	0.5	0.5			
Deisgner	0.3	0.3			
SCT (WBS 3.1.2)					
Faculty	0.3	0.3	0.4	0.1	0.1
Sr Research Scientist	1.5	2.0	1.3	0.2	0.2
Post Doc	2.5	3.0	3.0	2.3	0.8
Grad Student	2.0	2.0	2.0	1.0	1.0
RODs (WBS 3.1.3)					
Sr Research Scientist	1.0	1.0	0.9	0.1	0.1
Post Doc	2.0	0.0	1.9	0.4	0.4
Grad Student	1.0	1.0	1.0	0.5	0.5

Longer Term

Budget estimate for longer term Pre-operations and M&O:

FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12
0.542M	1.509M	1.582M	1.346M	1.055M	1.094M	1.201M	1.004M

Costs assumed largest at turn-on as we learn how to use the detector and make initial repairs. Assume a major intervention in FY11.

R & D for Silicon Tracking

Expect to focus:

- Primarily on Pixel R & D, since this system is likely to require earliest replacement of layers, and also is area of broadest U.S. contribution. Also expect any tracking upgrades to focus more heavily on pixels.

- Front-end electronics options for silicon, since all replacements not covered by spares will require electronics in technology current at the time.

- ROD R&D will be coupled to work on pixels.

Pixel R&D

- The useful lifetime of the innermost pixel layer is expected to be limited to a few years at design luminosity.
- However, there are substantial uncertainties in the actual radiation levels and realistic operating voltages => plan on replacing at least this layer(possibly more) early, since pixels are essential for tracking and required for all b-tagging, which is critical for high Pt physics.
- On a somewhat longer timescale, luminosities beyond 10^{34} will require major upgrades to the tracking system e.g. replacement of gas detectors by silicon(or something else), replacement of silicon strip detectors by pixels and increased radiation hardness(beyond the current 25MRad) for pixel detectors.
- R&D for >10^{34} is very challenging(it's taken us about 20 years to be comfortable with 10^{34}).

Pixel R&D Areas

- Electronics
  - Increase/understand radiation hardness > 100 MRad. This looks promising but much more study needed.
  - Follow the technology from 0.25µ to smaller feature sizes. Work on 0.17 µ or 0.13µ can begin very soon.
  - Reduce pixel size below 50x400µ. There is already significant confusion in at least innermost pixel layer.
- Sensors
  - A follow on to the successful ROSE collaboration is starting to address the 10^{35} challenge.
- Hybridization
  - Reduce the pitch of bump bonding to allow smaller pixels, or use redistribution in electronics.
  - Development of MCM-D technology to mostly eliminate kapton hybrids has been ongoing for some time and needs further development.
- Mechanics and systems issues
  - Reduce material and complexity of the mechanics/cooling. Material reduction directly improves electron and photon energy resolution and tracking performance.
  - Complexity of current cabling/cooling is formidable. Reliability will be problem.
  - Radioactivation of pixel elements is already significant at 10^{34}. There are as yet no good ideas about how to handle this for higher luminosities.

R&D Funding Profile

WBS Number	Descriptio	FY 03 (k$)	FY 04 (k$)	FY 05 (k$)	FY 06 (k$)	FY 07 (k$)	FY 08 (k$)	FY 09 (k$)	FY 10 (k$)	FY 11 (k$)	FY 12 (k$)
4.1	Silicon	0	238	859	1703	1684	2708	2405	366	0	0
4.1.1	Pixels	0	238	859	1492	1291	1968	1444	366	0	0
4.1.1.1	Replacement R&D	0	238	859	1492	0	0	0	0	0	0
4.1.1.1.1	Mechanics/Services	0	0	118	205	0	0	0	0	0	0
4.1.1.1.2	Sensors	0	0	105	114	0	0	0	0	0	0
4.1.1.1.3	Electronics	0	238	470	671	0	0	0	0	0	0
4.1.1.1.4	Hybrids	0	0	86	203	0	0	0	0	0	0
4.1.1.1.5	Module assembly	0	0	57	277	0	0	0	0	0	0
4.1.1.1.6	Test beam support	0	0	23	23	0	0	0	0	0	0
4.1.1.2	Replacement	0	0	0	0	1291	1968	1444	366	0	0
4.1.1.2.1	Mechanics/Services	0	0	0	0	339	501	630	366	0	0
4.1.1.2.2	Sensors	0	0	0	0	104	204	0	0	0	0
4.1.1.2.3	Electronics	0	0	0	0	512	596	304	0	0	0
4.1.1.2.4	Hybrids	0	0	0	0	192	283	186	0	0	0
4.1.1.2.5	Modules	0	0	0	0	143	384	324	0	0	0
4.1.2	SCT	0	0	0	0	110	387	387	0	0	0
4.1.2.1	Replacement R&D	0	0	0	0	110	387	387	0	0	0
4.1.2.1.1	Replacement R&D	0	0	0	0	110	387	387	0	0	0
4.1.3	ReadOut Drivers	0	0	0	210	283	353	574	0	0	0
4.1.3.1	Replacement R&D	0	0	0	210	283	0	0	0	0	0
4.1.3.2	Replacement - pixel RODs	0	0	0	0	0	353	574	0	0	0

R&D Labor Summary FTEs by FY

MANPOWER ESTIMATE SUMMARY IN FTEs

WBSNo: 4.1 | Funding Type: Program | 4/3/02 2:34:08 PM

Description: Silicon | Institutions: All | Funding Source : All

	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	Calcu-lated Total	Entered Total
Computing Profession											.0	.0
Electrical Engineer Sr		1.0	1.5	3.0	3.0	3.3	2.5				14.3	.0
Electrical Engineer Jr			1.3	2.5	3.5	3.5	1.0				11.7	.0
Mech Engineer Sr					1.0	1.5	1.5	.5			4.5	.0
Mech Engineer Jr			.5	1.0	1.5	2.0	1.5	.5			7.0	.0
Design - Draft			.3	.5	.5	.5	.5				2.3	.0
Adm Support											.0	.0
Electircal Technician			.3	.5	.1	.4	1.1				2.4	.0
Mech Technicial			.3	.5	.5	2.0	3.0	2.0			8.2	.0
Student			.3	.6	.3	2.0	2.0				5.1	.0
Physicist											.0	.0
Purchased Labor						2.0	2.0				4.0	.0
TOTAL LABOR	.0	1.0	4.3	8.6	10.4	17.1	15.1	3.0	.0	.0	59.6	.0